# PATENT ABSTRACTS OF JAPAN

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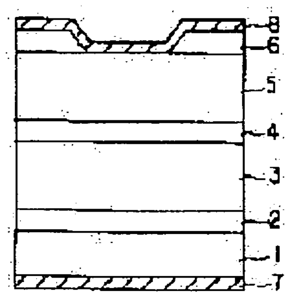
## (54) COMPOUND SEMICONDUCTOR ELEMENT

(57)Abstract:
PURPOSE: To accomplish high efficiency of a semiconductor element by providing a cubic crystal SiC substrate and a GaxAlxIn1-x-yN (0≤x≤1, 0≤y≤1) layer.
CONSTITUTION: A GaN buffer layer 2 of 1μm in thickness, a clad layer 3 consisting of p-GaAlInN of 1μm in thickness, a light-emitting layer 4 consisting of undoped GaAlInN of 0.1μm in thickness, are formed successively on a 3C-SiC substrate 1, and a semiconductor layer is composed of the above-mentioned layers. As the clad layer 5, consisted of final GaAlInN, is formed in N-type in this semiconductor laser, the taking-in of hydrogen into the p-GaAlInN clad layer 3 can be prevented, and a low resistance p-GaAlInN clad layer 3 can be formed. As a result, a high brightness short wavelength light-emitting element can be obtained.

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CLAIMS

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[Claim(s)]
[Claim 1] The compound semiconductor element characterized by providing a cubic SiC substrate and the Gax Aly In1-x-y N (0<=x<=1, 0<=y<=1) layer formed on the field (111) of this cubic SiC substrate.
[Claim 2] The conductivity type of said Gax Aly In1-x-y N layer is a compound semiconductor element according to claim 1 which is p mold and by which the n mold Gax Aly In1-x-y N layer is formed on this Gax Aly In1-x-y N layer.
[Claim 3] The conductivity type of said Gax Aly In1-x-y N layer is a compound semiconductor element according to claim 1 which is p mold and by which sequential formation of a Gax Aly In1-x-y N layer and the n mold Gax Aly In1-x-y N layer is carried out on this Alx Ga1-x-y Iny N layer.
[Claim 4] The compound semiconductor element which possesses a substrate and the Gax Aly In1-x-y N (0<=x<=1, 0<=y<=1) layer formed on this substrate, and is characterized by the substrate of said Gax Aly In1-x-y N layer and the crystal face which counters being N sides and which has pn junction.
[Claim 5] Said substrate is a compound semiconductor element according to claim 4 which consists of SiC.
[Claim 6] The field in which said Gax Aly In1-x-y N layer of said substrate is formed is a compound semiconductor element according to claim 5 which is Si side.
[Claim 7] Said substrate is a compound semiconductor element according to claim 4 characterized by forming the buffer layer which consists of sapphire and consists of GaxAly In1-x-y N of a single crystal on a substrate.
[Claim 8] p mold conductivity substrate and the p mold Gax Aly In1-x-y N (0<=x<=1, 0<=y<=1) layer formed on this p mold conductivity substrate, The compound semiconductor element characterized by providing the n mold Gax Aly In1-x-y N (0<=x<=1, 0<=y<=1) layer formed on this p mold Gax Aly In1-x-y N (0<=x<=1, 0<=y<=1) layer.
[Claim 9] Said p mold conductivity substrate is a compound semiconductor element according to claim 8 which consists of a p mold SiC.
[Claim 10] The compound semiconductor element according to claim 8 by which the electrode of a couple is formed on the field of an opposite hand, and the n mold Gax Aly In1-x-y N layer with said p mold Gax Aly In1-x-y N layer of said p mold conductivity substrate.

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[Translation done.]

## DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to a compound semiconductor element.
[0002]
[Description of the Prior Art] GaN which is an III-V group compound semiconductor containing nitrogen has a band gap as large as 3.4eV, and since it is a direct transition mold, it is expected as a charge of short wavelength light emitting device lumber. However, the crystal structure is a wurtzite mold, when it is easy to produce a lattice defect, p mold crystal of low resistance is hard to be obtained and epitaxial growth of the p type layer is carried out, using Mg especially as acceptor impurity as it is moreover shown below, since ionicity is large, all over an epilayer, hydrogen is spread, the rate of activation of an acceptor is lowered extremely, and the reduction in resistance is difficult for it.
[0003] Namely, although the double hetero mold laser structure which makes GaN a luminous layer and makes GaAlN a cladding layer is made as an experiment for some time, depending on wavelength, since luminescence wavelength is short, it is considered that the thickness of a cladding layer may be thin, and, as for the thickness of a cladding layer required since light is confined in a luminous layer in this case, the component is usually created by the about 0.2-micrometer thin cladding layer, as for GaN.
[0004] However, it became clear that the clad thickness of a cladding layer used so far is inadequate in order to also have played the role of confining a carrier in a luminous layer, and to confine [ according to research of this invention persons ] an electron and an electron hole in a luminous layer efficiently, for example in the case of the heterojunction which consists of nitrides, such as GaAlN and GaN, since the obstruction height in a hetero interface is low. However, when GaN does not have the substrate which carries out lattice matching to this and a thick film is grown up, it is thought for the lattice defect which distortion resulting from a lattice constant difference and a coefficient-of-thermal-expansion difference is accumulated, for this reason increases that it is difficult to grow up a thick layer.
[0005] Concretely, although, as for GaN, grid mismatching grows on large silicon on sapphire with about 15% for convenience in many cases, in a crystal mold's being different, the difference in a coefficient of thermal expansion is also great [ sapphire and GaN ]. For this reason, distortion of the interface by the grid mismatching of a substrate and GaN induces a lattice defect. Then, various approaches have been tried in order to reduce the effect of grid mismatching conventionally.
[0006] For example, although to ease distortion of an interface with a substrate by

carrying out thick-film growth of about 100 micrometers was tried when a vapor-phase-epitaxial-growth method (VPE law) was used as a crystal growth method, a good crystal, such as producing a crack, was not able to be grown up. Moreover, although to insert the amorphous layer by low dental-curing length on a substrate by metal-organic chemical vapor deposition (MOCVD law) was tried, the X diffraction width of face of grown-up GaN is wide, and the defect of high density still exists. It was impossible for a defect to increase rather, although thick-film growth was tried also in MOCVD growth, and to have grown up a thick film 3 micrometers or more.
[0007] On the other hand, it is reported by by irradiating an electron beam or heating in an inert atmosphere to GaN, recently to the problem of resistance of p mold crystal that resistance can be fallen substantially. However, it is difficult to obtain the component of a good property by this approach. That is, by the approach of irradiating an electron beam, it is necessary to irradiate the electron of high energy making an electron invade to sufficient depth, and easy to induce a crystal defect. Moreover, in heat treatment, although 800 degrees C or more need to be heated to remove the hydrogen incorporated in the epilayer and realize sufficient low resistance-ization, all over an epilayer, the hole by balking of N atom will be generated and a lattice defect will be caused at this temperature.
[0008] Furthermore, even if p type layer of low resistance is obtained, neither contact resistance with an electrode nor series resistance improves, but it is also necessary for improvement in the component engine performance to reduce these resistance.
[0009]
[Problem(s) to be Solved by the Invention] Thus, since it would produce the lattice defect of high density if it grows up a GaN system compound layer thickly in creation of a component although the expectation of GaN as a charge of light emitting device lumber is great, it had problems, like the reduction in resistance of that a limitation is in the thickness of a cladding layer, p type layer, etc. is difficult.
[0010] The object of this invention is by growing up Gax Aly In1-x-y N of high quality to offer the compound semiconductor element of high performance.
[0011]
[Means for Solving the Problem] This invention (claim 1) offers the compound semiconductor element characterized by providing a cubic SiC substrate and the Gax Aly In1-x-y N (0<=x<=1, 0<=y<=1) layer formed on the field (111) of this cubic SiC substrate.
[0012] Moreover, this invention (claim 4) possesses a substrate and the Gax AlyIn1-x-y N (0<=x<=1, 0<=y<=1) layer formed on this substrate, and offers the compound semiconductor element which is characterized by the substrate of said Gax Aly In1-x-y N layer and the crystal face which counters being N sides and which has pn junction.
[0013] Furthermore, the p mold Gax Aly In1-x-y N (0<=x<=1, 0<=y<=1) layer by which this invention (claim 8) was formed on p mold conductivity substrate and this p mold conductivity substrate, The compound semiconductor element characterized by providing the n mold Gax Aly In1-x-y N (0<=x<=1, 0<=y<=1) layer formed on this p mold Gax Aly In1-x-y N (0<=x<=1, 0<=y<=1) layer is offered.
[0014]
[Function] Generally, the process in which a defect is introduced into a growth phase is divided into two kinds. It is introduced by distortion resulting from the differential thermal expansion of a substrate and a growth phase, when it is introduced more distorted and other one is cooled [ to which one originates in the lattice constant difference of a substrate and a growth phase during growth ] from growth temperature

to a room temperature after growth termination. Until now, since the defects in a growth phase have been considered to be the causes with a main lattice strain with the former substrate, with the GaAlInN system ingredient with which the suitable substrate which should grow is not found out, it has been thought that it is very difficult to obtain the growth phase of a low rearrangement.

[0015] However, according to research of this invention persons, since the growth temperature of GaN was as high as 1000 degrees C or more, at growth temperature, most rearrangements are canceled by annealing and it became clear that most rearrangements observed originate in the are recording of distortion at the time of cooling by the difference of a big coefficient of thermal expansion with a substrate. This result is remarkable especially when it is the field (C side) considered that a growth side tended to carry out motion of a rearrangement (0001). Therefore, in the case of the GaN system compound, for defective reduction, it turned out that it is more important than a lattice constant that a differential thermal expansion uses a near substrate rather.

[0016] It is tried for 6 H-SiC to grow up a GaN layer on the 6 H-SiC substrate as GaN with the same crystal structure since it is hexagonal and a lattice constant is also near. However, the defect of a GaN layer in which it grew up on 6 H-SiC did not decrease so much. Since the differential thermal expansion of 6 H-SiC and GaN is large, this is considered. However, the thermal expansion in a direction parallel to the field (111) of 3C-SiC which is a cubic also in the same SiC, and the thermal expansion in a direction parallel to the a-axis of GaN are dramatically near.

[0017] Change (deca) of the lattice constant to the temperature (T) of GaN and 3C-SiC is shown in drawing 1 . In the field from growth temperature to near 100 degree C which motion of a rearrangement can disregard mostly, the distortion by the differential thermal expansion of the GaN layer and 3C-SiC substrate which are an epilayer is 0.001% or less, and by using 3C-SiC as a substrate shows that a fast reduction of epilayer defect density is expectable.

[0018] Moreover, although 3C-SiC is a cubic and its lattice constant is also as large as 0.436nm, the distance between grids is 0.308nm and is as near as 0.318nm which is the lattice constant of GaN in a field (111). Then, by growing up GaN into the field (111) of 3C-SiC, it becomes possible to grow up GaN of high quality by the low rearrangement.

[0019] Furthermore, when the distortion by the differential thermal expansion of a substrate and an epilayer decreased substantially, thick-film growth of 3 micrometers or more is attained, distortion produced by the difference in a lattice constant by performing thick-film growth is eased, and growth of the layer of high quality is attained more by the low rearrangement. Furthermore, the semiconductor device of high performance using this epilayer can be obtained.

[0020] Moreover, as mentioned above, since the obstruction height of a cladding layer in a hetero interface is low, in order to confine an electron and an electron hole in a luminous layer still more efficiently, at least 1-micrometer thickness is required [ it has also achieved the duty which confines a carrier in a luminous layer, and ] for it by the nitride system, when creating the light emitting device of a double heterojunction mold especially using such an epilayer. On the other hand, it is possible to realize clad thickness sufficient the closing depth of a carrier by creating the component which consists of GaN on the field (111) of a 3C-SiC substrate. Mixed crystal with GaN, aluminum, and In is also the ingredient of the same nitride system as GaN, and since a coefficient of thermal expansion hardly changes, growth of the layer of the high quality of thick thickness is possible for it similarly.

[0021] Moreover, III-V group compounds, such as GaN, AlN, InN, etc. which are used by this invention, are III also to the field which has the crystal structure of a URUTSU mold and usually turns into a crystal growth side (1000). There is 2 kinds of field, Ath page [ to which a group element governs a property ], and Bth page to which V group element governs property, bearing. According to research of this invention persons, GaAlInN When it grows up so that the Ath page may come to the field by the side of a substrate to the growth direction, it is three-dimensions growth (since growth rates differ on a growth side). Although it was easy to carry out a phenomenon, when it grew up so that the Bth page might come reversely [ this ] to the field by the side of a substrate to the growth direction, two dimensional crystal growth (phenomenon in which a growth side becomes homogeneity) was carried out, and the thing in which column-like heights occur and which a defect decreases was found out. Therefore, it is possible to attain high performance-ization of a component by using such a good GaAlInN epitaxial layer especially for the compound semiconductor element which has pn junction.

[0022] Although distinction with Si side and C side can do SiC as shown in drawing 2 (a) and (b) when the above 3C-SiC(s) are used for a substrate here, Ga corresponds to Si and, as for GaN, N corresponds to C. Therefore, it is desirable to grow up GaAlInN so that N atom of the Bth page may counter Si side of a SiC substrate and a growth side may turn into the Ath page. For this reason, by specifically growing up an epitaxial layer by well-known vapor growth on the SiC substrate out of which Si side has come to the front face, a polarity is controllable so that the Bth page comes to the field by the side of a substrate.

[0023] Furthermore, when growing up GaN by metal-organic chemical vapor deposition on silicon on sapphire, ammonia is usually used as a nitrogen raw material, but under the elevated temperature near [ which is growth temperature ] 1000 degree C, since an AlN layer is formed in a sapphire substrate front face and a sapphire substrate front face turns into the Bth page, the growth side of GaN turns into the Bth page. However, in this way, for the condition that cracking severity is low, there are B growth sides when using the ammonia which runs short of N atoms supplied, and N atom comes out to a front face, it is not stable and a growth side is III at the Ath page. The condition that a group element comes out to a front face is stable. Therefore, when growing up GaN directly on silicon on sapphire, in order to suppress installation of a defect, to grow up the crystal of high quality and to acquire good pn junction, it is important [ it is difficult to grow up the crystal of high quality and ] to control the polarity of a crystal and to make a growth side into the Ath page.

[0024] Here, for the polarity of the crystal in the case of growing up III-V group compounds, such as GaN, on nonpolar group plates, such as sapphire, the element which sticks to a substrate front face first is III. It is determined by whether it is a group element or it is V group element. When V group element adsorbs first, the Ath page turns into a growth side, and it is III. When a group element adsorbs first, the Bth page turns into a growth side. Therefore, as mentioned above, in order to make a growth side into the Ath page, it is III. What is necessary is not to be based on the class of group element but just to make N atom which is a V type element adsorb first. For this reason, when using a sapphire substrate, in order to stop effectively the ammonia molecule which works as a nitrogen supply source of V group element, or its decomposition product in a front face, it is desirable to set preferably 700 degrees C or less of substrate temperature as 600 degrees C or less, and to form a buffer layer.

[0025] In this invention, the buffer layer for above-mentioned polar control has a good

.single.crystal. In controlling thickness strictly in order not to lose the information on the crystal orientation of a substrate, the polycrystal used conventionally and if amorphous [ it becomes what, and ], by the approach using a single crystal buffer layer to the polarity of a crystal being uncontrollable, it is because there is such no constraint. Furthermore, when InN, GaInN, AlInN, GaAlInN, etc. containing In are used, growth of the single crystal of high quality is possible even for low temperature 600 degrees C or less, and it is especially effective. Here, drawing 3 (a) and (b) are the mimetic diagrams showing the GaN layer from which field bearing which carried out crystal growth on the sapphire substrate differs, respectively. It turns out that a growth side will turn into the Bth page if GaN is directly grown up on a substrate as illustrated, a growth side will turn into the Ath page and N atom of the Bth page will counter a substrate side on the other hand if GaN is grown up through a buffer layer.
[0026] By controlling a polarity by this invention as mentioned above, and growing up the epilayer of Gax Aly In1-x-y N selectively so that the Ath page may turn into a growth side to the growth direction, a rearrangement and distortion decrease by leaps and bounds, and the Gax aluminum1-x-y Iny N crystal growth of a low defect of them becomes possible, and they become possible [ attaining high performance-ization of the compound semiconductor element which has the pn junction using this ].
[0027] In addition, it cannot be overemphasized that the compound semiconductor element which has such pn junction here may be what has junction of a double hetero mold. Moreover, in this invention, the polarity of the crystal which grows can be judged by RBS (Rutherford back scattering).
[0028] Furthermore, as mentioned above, in order to have to gather the rate of activation of p mold dopant in order to obtain p type layer of low resistance, and to gather the rate of activation, it is first known for a compound semiconductor element like this invention that it is important to reduce picking ****** of the hydrogen of a under [ a crystal ]. That is, when SIMS analysis of the GaN which carried out MOCVD growth is carried out, a lot of hydrogen is mixing and the hydrogen is considered to reduce the rate of activation of p mold dopant.
[0029] Here, the impurity incorporated during a crystal is usually incorporated out of a raw material during growth in many cases. However, it became clear by research of this invention persons for the hydrogen in GaN not to be incorporated by the crystal during growth, but to mainly be incorporated by diffusion from a front face in the cooling process after growth. Therefore, if the amount from which hydrogen is incorporated by p type layer by the cooling process decreases, the rate of activation of p mold dopant will increase, and creation of p type layer of low resistance will be attained.
[0030] p type layer is partly considered according to a cooling process as an approach which is made not to be exposed to hydrogen. For example, generally, since it is known that the diffusion rate of hydrogen is slow in n type layer, it becomes possible by growing up n type layer as a cap layer in the culmination of growth, and p type layer being made not to be exposed by the cooling process to hydrogen to control picking ****** of the hydrogen to p type layer. It is not carried out with the component by which n type layer and p type layer being formed continuously and growing up n type layer as a cap layer in the culmination of growth generally work first with the component using a GaN system ingredient until now.
[0031] In addition, in order to obtain p type layer of GaN, Mg was usually added, but since control of concentration and a concentration profile was remarkable and conventionally difficult Mg in a low-concentration field, for formation of pn junction, it had to add to the concentration near a solid-solution limit community. However,

.although the steep concentration profile was obtained in order that such high-concentration Mg might cause rapid diffusion, crystal quality deteriorated remarkably and n type layer of high quality was not able to grow on this.

[0032] However, since it becomes without it turning out that Mg can be added with a sufficient controllability by the approach of addition according to research of this invention persons, depositing on a crystal front face if unnecessary in superfluous addition, and damaging a front face, it also becomes possible to grow up quality **** n type layer on it. Furthermore, if it becomes possible to grow up n type layer, since the hydrogen to p type layer will carry out picking ** rare ****** and the rate of activation of p mold dopant will increase as mentioned above on p type layer, in this invention, the component structure of providing n type layer of high quality on p type layer of low resistance is realizable.

[0033] After specifically adding Mg beforehand also to a buffer layer before growing up p type layer, the p mold GaAlInN layer which doped Mg is grown up, and the n mold GaAlInN layer which doped Si is grown up after that. Thereby, since p type layer is not exposed to hydrogen by the cooling process, growth of the p mold GaAlInN layer of low resistance is attained.

[0034] Moreover, also in a low concentration field, it is compatible in a good controllability and a steep concentration change by supplying Mg raw material of a minute amount beforehand. Therefore, it is possible to attain high performance-ization of a component, without spoiling dependability, since it becomes controllable [ the maximum concentration which can control generating of a crystal defect ] to 1/2 or less about Mg concentration. Furthermore, even when a substrate is n mold, it is possible by growing up n type layer into the last layer, and removing n type layer after cooling to form pn junction in p type layer of low resistance.

[0035] Also besides having explained above, the device of the cooling process after growth termination can be considered as the technique of p mold stratification low resistance. There is little desorption of the nitrogen atom in which the quality of a growth phase is reduced at the temperature of 900 degrees C or less, and it can be mostly disregarded below 700 degrees C. On the other hand, trespass of the hydrogen atom which raises resistance of p type layer begins from 800 degrees C or less, and becomes remarkable below 700 degrees C. Therefore, it is possible by cooling in nitrogen content ambient atmospheres, such as ammonia, from growth temperature to the temperature of about 900-700 degrees C, and cooling in inert gas at the temperature not more than it to prevent balking of harmful nitrogen and trespass of hydrogen simultaneously.

[0036] Since this approach does not have a limit in the time amount which exposes a growth crystal to inert gas at the time of an elevated temperature unlike the approach of making it seceding from hydrogen by after treatment, it can be quenched in a short time and can prevent degradation of crystal quality.

[0037] As mentioned above, by performing the cooling process after growth termination in the ambient atmosphere which does not contain hydrogen, balking of nitrogen and the trespass of hydrogen in this cooling process can be prevented simultaneously, growth of the p mold GaInAlN layer of high quality is attained by low resistance, and this leads to implementation of the short wavelength light emitting device of high brightness.

[0038] Next, this invention persons acquired the following knowledge, as a result of inquiring wholeheartedly that contact resistance with p type layer of the above low resistance and an electrode etc. should be reduced.

[0039] That is, GaN was conventionally formed on the sapphire substrate, and since a sapphire substrate was insulation, it was grown up on the sapphire substrate in order of the n mold GaN layer and the p mold GaN layer, formed the exposed surface in the n mold GaN layer with resistance low general comparatively, and formed the electrode on the n mold GaN layer and the p mold GaN layer. However, if it takes into consideration that it is difficult to form the p mold GaN layer of low resistance in the topmost part as mentioned above, it is possible to make it grow up on a sapphire substrate in order of a p mold GaN layer and an n mold GaN layer, to form an exposed surface in a p mold GaN layer, and to form an electrode on a p mold GaN layer and an n mold GaN layer. However, the path for which a current flows a p mold GaN layer with such structure where a current flows a p mold GaN layer to film surface inboard since resistance is far high is longer than an n mold GaN layer, series resistance of a component cannot become high and, as for a p mold GaN layer, the component of high performance cannot be obtained. Moreover, also in structure, the p mold GaN has high contact resistance with an electrode, and all have a difficulty also at this point.
[0040] On the other hand, in this invention, all above-mentioned problems are solvable by having used p mold conductivity substrate instead of the sapphire substrate, and having considered as the component structure where it was made to grow up on this p mold conductivity substrate in order of a p mold GaN layer and an n mold GaN layer. In p type layer which has n type layer as a cap layer being low resistance comparatively according to this component structure, namely, only by forming an electrode on the rear face of p mold conductivity substrate, and an n mold GaN layer Since the problem [ electrode / p type layer and ] of contact resistance is solved by inclusion of p mold conductivity substrate and a current flows along the direction of thickness in p type layer, the path is short, and series resistance of a component is also suppressed, as a result it becomes realizable [ a high brightness short wavelength light emitting device ].

[0041]
[Example] Hereafter, the various examples of this invention are explained with reference to a drawing.
[0042] Drawing 4 is the outline block diagram of the semiconductor laser concerning one example of this invention. The cladding layer 3 (a Mg dope) which consists of p-GaAlInN of the thickness of 2 or 1 micrometer of GaN buffer layers with a thickness of 1 micrometer (undoping) on the 3C-SiC substrate 1 1x1016-1x1019cm-3, for example, 1x1017cm-3, The luminous layer 4 which consists of undoping GaAlInN with a thickness of 0.1 micrometers, and the cladding layer 5 (an Si dope [ undoping or ]) which consists of n-GaAlInN with a thickness of 1 micrometer Sequential formation of 1x1016-1x1019cm-3, 1x1017cm-3 [ for example, ], is carried out, and semiconductor laser is constituted by it. the inside of drawing, and a reference mark 6 -- SiO2 from -- the becoming current blocking layer, and 7 and 8 show a metal electrode, respectively.
[0043] In this semiconductor laser, since the cladding layer 5 which consists of the last GaAlInN is used as n mold, incorporation of the hydrogen to the cladding layer 3 which consists of p-GaAlInN can be prevented, and the formation of a cladding layer 3 which consists of p-GaAlInN of low resistance is possible. Consequently, it becomes realizable [ a high brightness short wavelength light emitting device ].
[0044] Moreover, since the cladding layers 3 and 5 which consist of a p mold and an n mold GaAlInN are formed in the thickness of 1 micrometer, it becomes possible to pour a current into a luminous layer 4 efficiently, and improvement in luminous efficiency

can be aimed at.

[0045] Next, the crystal growth approach adopted in order to manufacture the semiconductor laser shown in drawing 4 is explained. Drawing 5 is the outline block diagram showing the growth equipment used in order to manufacture the semiconductor laser shown in drawing 4 . In the growth equipment shown in drawing 5 , raw material mixed gas is introduced from a gas inlet 12 in a coil 11. And the gas in a coil 11 is exhausted from the flueing opening 13. The susceptor 14 made from carbon is arranged in the coil 11, and the sample substrate 15 is laid on this susceptor 14. Moreover, induction heating of the susceptor 14 is carried out with a high frequency coil 16.

[0046] First, it is laid on a susceptor 14, using as the sample substrate 15 the SiC substrate out of which the field (111) came. High grade hydrogen is introduced by the flow rate of 1l./m from the gas installation tubing 12, and the atmospheric air in a coil 11 is permuted. Subsequently, the flueing opening 13 is connected to a rotary pump, and the inside of a coil 11 is exhausted, it is made reduced pressure, and an internal pressure is set as the range of 20-300torr.

[0047] Subsequently, NH3 as an N raw material after setting substrate temperature as 450 to 900 degree C With gas, an organic metal aluminum compound, an organic metal Ga compound, and an organic metal In compound are introduced, and crystal growth is performed. In addition, as an organic metal aluminum compound, it is aluminum (CH3)3, for example. Or as aluminum (C two H5)3 and an organic metal Ga compound For example, Ga3 (CH3) or as Ga (C two H5)3 and an organic metal In compound for example, In (CH3)3 or -- as In (C two H5)3 and N raw material -- NH3 everything but gas -- for example, N two H4, CH3 2 N3, 2 (CH3) NH2, and C2 H5 N3 It can use.

[0048] At this time, in doping, it also introduces the raw material for doping simultaneously. As a raw material for doping, it is SiH4 as an object for n molds. Si hydride [ like ] and Si4 (CH3) An organic metal Si compound [ like ], an Se hydride like H2 Se, and Se2 (CH3) An organic metal Se compound [ like ] can be used. Moreover, an organic metal Mg compound like Cp2 Mg (magnesium cyclopentadienyl), MCp2 Mg (methylcyclopentadienyl magnesium), and i-PrCp3 Mg (isopropyl magnesium cyclopentadienyl) as an object for p molds and Zn2 (CH3) An organic metal Zn compound [ like ] etc. can be used.

[0049] Specifically in manufacture of semiconductor laser shown in drawing 4 , it is NH3 as a raw material. 1x10-3 mol/min and Ga(C two H5) 3 1x10-5 mol/min and In (CH3) 3 1x10-6 mol/min and aluminum3 (CH3) It grew up by introducing by the flow rate of 1x10-6 mol/min. The total flow of 75torr(s) and material gas set substrate temperature 700 degrees C, and the pressure set it to 1l. / min. As a dopant, Mg was used for n mold dopant at Si and p mold dopant. Si doped the silane (SiH4), when Mg mixed magnesium cyclopentadienyl (Cp2 Mg) in material gas, respectively.

[0050] Thus, when the cleavage of the obtained semiconductor laser wafer was carried out and the laser component of 300 micrometers of cavity length was constituted, blue glow laser oscillation was checked by the pulse operation of pulse width sec of 100micro at liquid nitrogen temperature.

[0051] In this example, although GaN was used as a buffer layer, the p mold GaAlN or the p mold GaAlInN may be grown up.

[0052] Drawing 6 is the outline block diagram of LED concerning other examples of this invention. Sequential formation of the p-GaN buffer layer (10 micrometers) 22, the p-GaInAlN layer (2 micrometers) 23, and the n-GaInAlN (2 micrometers) layer 24 is carried out on the 3C-SiC substrate 21. Reference marks 25 and 26 all show a metal

electrode among drawing.

[0053] LED shown in drawing 6 can be manufactured like the case where the semiconductor laser equipment shown in drawing 4 is manufactured using the growth equipment shown in drawing 5 .

[0054] Drawing 7 shows the condition of having embedded the LED chip 31 by this example in the resin case 32 which served as the lens. A reference mark 33 shows an internal lead and 34 shows an external lead, respectively. Blue luminescence of about 5 mcd(s) was checked about LED embedded in the resin case shown in drawing 5 .

[0055] Drawing 8 is the outline block diagram of the semiconductor laser concerning other examples of this invention. It is formed on the 3C-SiC substrate 41 at the thickness whose GaN buffer layer (undoping) 42 is 1 micrometer. The cladding layer 43 (an Si dope [ undoping or ]) which consists of n-GaAlInN on it It is formed in the thickness whose 1x1016-1x1019cm-3, 1x1017cm-3 [ for example, ], are 1 micrometer. It is formed in the thickness whose luminous layer 44 which consists of undoping GaAlInN on it is 0.1 micrometers, and the cladding layer 45 (Mg dope and 1x1016-1x1019cm-3, for example, 1x1017cm-3) which consists of p-GaAlInN on it further is formed in the thickness which is 1 micrometer. the inside of drawing, and a reference mark 46 -- SiO2 from -- the becoming current blocking layer, and 47 and 48 show a metal electrode, respectively.

[0056] In this semiconductor laser, since p mold and the n mold GaAlInN layer which are a cladding layer can be formed in the thickness of 1 micrometer through a GaN buffer layer, it becomes possible to pour a current into a luminous layer efficiently, and improvement in luminous efficiency can be aimed at. In addition, in this semiconductor laser, by forming an n mold GaAlInN layer on a p-GaAlInN layer, and removing this n type layer after cooling, incorporation of the hydrogen to a p-GaAlInN layer can be prevented, and formation of the p-GaAlInN layer of low resistance is possible. Consequently, it becomes realizable [ high brightness short wavelength semiconductor laser ].

[0057] Drawing 9 is the outline block diagram of the semiconductor laser concerning the example of further others of this invention. (111) It is formed on the 3C-SiC substrate 51 out of which the field came at the thickness whose GaN buffer layer 52 (undoping) is 1 micrometer. The cladding layer 53 (a Mg dope) which consists of p-GaAlInN on it It is formed in the thickness whose 1x1016-1x1019cm-3, 1x1017cm-3 [ for example, ], are 1 micrometer. It is formed in the thickness whose luminous layer 54 which consists of undoping GaAlInN on it is 0.1 micrometers. The cladding layer 55 (an Si dope [ undoping or ]) which consists of n-GaAlInN on it It is formed in the thickness whose 1x1016-1x1019cm-3, 1x1017cm-3 [ for example, ], are 1 micrometer, and the current blocking layer 56 which consists of p-GaAlInN, and the cap layer 57 which consists of n-GaAlInN are formed on it, respectively. Reference marks 58 and 59 show a metal electrode.

[0058] At the semiconductor laser concerning this example, since the GaN buffer layer is formed on the field (111) of a 3C-SiC substrate, GaN of high quality can be grown up by the low rearrangement. Moreover, since p mold and the n mold GaAlInN layer which are a cladding layer were formed in the thickness of 1 micrometer, it becomes possible to pour a current into a luminous layer efficiently, and improvement in luminous efficiency can be aimed at.

[0059] The case where the semiconductor laser concerning this example is grown up using the growth equipment shown in drawing 5 is explained below.

[0060] First, the 3C-SiC substrate out of which the field (111) came is laid on a

susceptor 14. High grade hydrogen is introduced per minute 11 times from the gas installation tubing 12, and the atmospheric air in a coil 11 is permuted. Subsequently, the flueing opening 13 is connected to a rotary pump, the inside of a coil 11 is decompressed, and an internal pressure is set as the range of 20-300torr.

[0061] Subsequently, H2 after reducing substrate temperature at 450 to 900 degree C It is gas NH3 Gas and N two H4 The organic compound two H2, for example, (CH3), 2 N, containing gas or N While changing, it is the organic Ga compound (CH3) 3, for example, Ga. Or Ga3 (C two H5) It grows up by introducing. They are the organic aluminum compound (CH3) 3, for example, aluminum, or aluminum (C two H5)3, and the organic In compound (CH3) 3, for example, In, simultaneously. Or In3 (C two H5) It introduces and addition of aluminum and In is performed.

[0062] In doping, it also introduces the raw material for doping simultaneously. as the raw material for doping -- as the object for n molds -- Si hydride 4, for example, SiH, or -- as the organic Si compound (CH3) 4, for example, Si, and the object for p molds -- organic Mg compound, for example, (C five H5), 2 Mg, 2 (C six H7) Mg, or organic Zn compound (CH3) 2, for example, Zn, etc. -- it is used.

[0063] Specifically in manufacture of semiconductor laser shown in drawing 9 , it is NH3 as a raw material. 1x10-3 mol/min and Ga(CH3) 3 1x10-5 mol/min and aluminum3 (CH3) 1x10-6 mol/min and In(CH3) 3 1x10-6 mol/min installation is carried out, and it is made to grow up. Substrate temperature made 1 l/min the total flow of 1000 degrees C, pressure 76torr, and material gas. Mg was used for the dopant as Si and a p mold dopant as an n mold dopant. As a raw material for dopants, Si (CH3)4 and Cp2 Mg were used.

[0064] When picking ****** of the hydrogen at the time of cooling was controlled, the temperature of 800 degrees C thru/or 850 degrees C cooled in ammonia, and cooled in the argon after that.

[0065] Drawing 10 is the outline block diagram of the semiconductor laser concerning other examples of this invention. (111) It is formed on the 3C-SiC substrate 61 out of which the field came at the thickness whose GaN buffer layer (undoping) 62 is 1 micrometer. The cladding layer 63 (an Si dope [ undoping or ]) which consists of n-GaAlInN on it It is formed in the thickness whose 1x1016-1x1019cm-3, 1x1017cm-3 [ for example, ], are 1 micrometer. It is formed in the thickness whose barrier layer 64 which consists of undoping GaAlInN on it is 0.1 micrometers, and the cladding layer 65 (Mg dope and 1x1016-1x1019cm-3, for example, 1x1017cm-3) which consists of p-GaAlInN on it is formed in the thickness which is 1 micrometer. Reference marks 66 and 67 show a metal electrode among drawing.

[0066] In the semiconductor laser concerning this example, since p mold and the n mold GaAlInN layer which are a cladding layer were formed through the GaN buffer layer at the thickness of 1 micrometer on the 3C-SiC substrate, it becomes possible to pour a current into a luminous layer efficiently, and improvement in luminous efficiency can be aimed at.

[0067] Drawing 11 is the outline block diagram of the semiconductor laser concerning other examples of this invention. (111) On the 3C-SiC substrate 71 out of which the field has come, it is formed at the thickness whose GaN buffer layer (undoping) 72 is 1 micrometer. The cladding layer 73 (a Mg dope) which consists of p-GaAlInN on it It is formed in the thickness whose 1x1016-1x1019cm-3, 1x1017cm-3 [ for example, ], are 1 micrometer. It is formed in the thickness whose luminous layer 74 which consists of undoping GaAlInN on it is 0.1 micrometers. Furthermore, the cladding layer 75 (undoping or Si dope, and 1x1016-1x1019cm-3, for example, 1x1017cm-3) which

consists of n-GaAlInN is formed on it at the thickness which is 1 micrometer. The reference marks 76 and 77 in drawing show a metal electrode.
[0068] In this semiconductor laser, since the last GaAlInN layer is used as n mold, incorporation of the hydrogen to a p-GaAlInN layer can be prevented, and formation of the p-GaAlInN layer of low resistance is possible. Consequently, it becomes realizable [ high brightness short wavelength semiconductor laser ].
[0069] Moreover, since p mold and the n mold GaAlInN layer which are a cladding layer can be formed in the thickness of 1 micrometer through a GaN buffer layer, it becomes possible to pour a current into a luminous layer efficiently, and improvement in luminous efficiency can be aimed at.
[0070] Drawing 12 is the outline block diagram of the semiconductor laser concerning other examples of this invention. (111) On the 3C-SiC substrate 81 out of which Si side of a field came, the cladding layer 85 which consists of p-GaAlInN of the thickness of 84 or 1.5 micrometers of luminous layers it is thin from the undoping GaAlInN of the thickness of 83 or 0.1 micrometers of cladding layers it is thin from n-GaAlInN of the thickness of 82 or 1.5 micrometers of n-GaAlInN buffer layers with a thickness of 1 micrometer is formed, and the current blocking layer 86 which consists of n-GaAlInN, and the contact layer 87 which consists of p-GaAlInN be formed on it Reference marks 88 and 89 all show a metal electrode among drawing.
[0071] At the semiconductor laser concerning this example, since the n-GaAlInN buffer layer forms in the field (111) of a 3C-SiC substrate, the GaAlInN buffer layer of high quality can be grown up by the low rearrangement. Moreover, since p mold and the n mold GaAlInN layer which are a cladding layer were formed in the thickness of 1.5 micrometers, it becomes possible to pour a current into a luminous layer efficiently, and improvement in luminous efficiency can be aimed at. When the X diffraction estimated the wafer obtained actually, it turned out that it is checked that the crystal defect is decreasing by leaps and bounds, and implementation of a high brightness short wavelength light emitting device can be expected.
[0072] Drawing 13 is the outline block diagram of the semiconductor laser concerning other examples of this invention. In this example, in order to arrange the polarity of an epitaxial growth phase, 6 H-SiC substrate out of which Si side came to the growth side was used. On the 6 H-SiC substrate 91, the GaN buffer layer (undoping) 92 with a thickness of 1 micrometer is formed, the cladding layer 93 (Si dope) which consists of n-GaAlInN with a thickness of 1 micrometer is formed on it, the luminous layer 94 which consists of undoping GaAlInN with a thickness of 0.1 micrometers is formed on it, and the cladding layer 95 (Mg dope) which consists of p-GaAlInN with a thickness of 1 micrometer is further formed on it. The current blocking layer which a reference mark 96 becomes from n-GaAlInN, and 97 and 98 show a metal electrode among drawing, respectively.
[0073] In this semiconductor laser, n-current blocking layer 96 was formed on the p-cladding layer 95, and incorporation of the hydrogen to the p-cladding layer 95 is prevented.
[0074] Drawing 14 is the outline block diagram of the semiconductor laser concerning other examples of this invention. It is formed at the thickness whose GaN buffer layer (undoping) 102 is 1 micrometer on the 6 H-SiC substrate 101 out of which Si side came. The cladding layer 103 (an Si dope [ undoping or ]) which consists of n-GaAlInN on it It is formed in the thickness whose 1x1016-1x1019cm-3, 1x1017cm-3 [ for example, ], are 1 micrometer. It is formed in the thickness whose luminous layer 104 which consists of undoping GaAlInN on it is 0.1 micrometers. The cladding layer 105

(Mg dope and 1x1016-1x1019cm-3, for example, 1x1017cm-3) which consists of p-GaAlInN on it is formed in the thickness which is 1 micrometer. A reference mark 106,107 shows a metal electrode among drawing.
[0075] In the semiconductor laser concerning this example, since p mold and the n mold GaAlInN layer which are a cladding layer were formed in the thickness of 1 micrometer, it becomes possible to pour a current into a luminous layer efficiently, and improvement in luminous efficiency can be aimed at.
[0076] Moreover, in said example, although polar control of an epitaxial layer was performed using 6 H-SiC substrate, another substrates, such as silicon on sapphire, may be used and the example is shown in drawing 15 , and 16 and 17. In addition, in these examples, each checked the polarity of a crystal by RBS.
[0077] Drawing 15 is the outline block diagram of the semiconductor laser concerning the example which used silicon on sapphire. On silicon on sapphire 111, the AlN buffer layer 112 is formed at the growth temperature of 650 degrees C, sequential formation of the contact layer 113 which consists of p-GaAlInN on it, the cladding layer 114 which consists of p-InGaAlInN, the luminous layer 115 which consists of GaAlInN, and the cladding layer 116 which consists of n-GaAlInN is carried out, and semiconductor laser is constituted. the inside of drawing, and a reference mark 117 -- SiO2 from -- the becoming current blocking layer and 118,119 show a metal electrode, respectively.
[0078] In this semiconductor laser, the n-cladding layer 116 was formed above the p-cladding layer 114, and incorporation of the hydrogen to the p-cladding layer 114 is prevented.
[0079] Drawing 16 is the outline block diagram of the semiconductor laser concerning other examples which used silicon on sapphire. On silicon on sapphire 121, it is formed at the growth temperature whose AlN buffer layer 122 is 650 degrees C, sequential formation of the contact layer 123 which consists of p-InGaAlN on it, the cladding layer 124 which consists of p-InGaAlN, the luminous layer 125 which consists of InGaAlN, and the cladding layer 126 which consists of n-InGaAlN is carried out, and semiconductor laser is constituted. A reference mark 127,128 shows a metal electrode among drawing, respectively.
[0080] In this semiconductor laser, 126 layer of n-InGaAlN were formed above the p-InGaAlN layer 124, and incorporation of the hydrogen to the p-InGaAlN layer 124 is prevented.
[0081] Drawing 17 is the outline block diagram of the semiconductor laser concerning the example of further others which used silicon on sapphire. The n-GaAlInN buffer layer 132 is formed on silicon on sapphire 131, sequential formation of the cladding layer 133 which consists of n-GaAlInN on it, the luminous layer 134 which consists of undoping GaAlInN, and the cladding layer 135 which consists of p-GaAlInN is carried out, the current-element layer 136 which consists of n-GaAlInN, and the contact layer 137 which consists of p-GaAlInN are formed on it, and semiconductor laser is constituted. A reference mark 138,139 shows a metal electrode among drawing, respectively.
[0082] This semiconductor laser was manufactured like the example shown in drawing 4 using the equipment shown in drawing 5 . When the X diffraction estimated the obtained semiconductor laser, it turned out that it is checked that the crystal defect is decreasing by leaps and bounds, and implementation of a high brightness short wavelength light emitting device can be expected.
[0083] Drawing 18 is the outline block diagram of the semiconductor laser concerning other examples of this invention. The p-GaAlInN buffer layer 152 is formed on the p-

SiC substrate 151, the p-GaAlInN cladding layer 153 is formed on it, the undoping GaAlInN luminous layer 154 is formed on it, and the n-GaAlInN cladding layer 155 with a thickness of 1 micrometer is further formed on it. the inside of drawing, and a reference mark 156 -- SiO2 from -- the becoming current blocking layer and 157,158 show a metal electrode, respectively.

[0084] In this semiconductor laser, since p mold electrode is connected through p mold conductivity substrate, using a p-SiC substrate as a substrate, contact resistance and series resistance can be decreased substantially, and implementation of a high brightness short wavelength light emitting device can be expected.

[0085]

[Effect of the Invention] As explained above, according to this invention, the rearrangement and distortion which originate in the difference in the coefficient of thermal expansion of a substrate and a growth phase, and generate a GaAlInN layer by growing up to be the field (111) of a cubic SiC substrate decrease by leaps and bounds, growth of the GaAlInN layer of a low defect is attained, and high performance-ization of a semiconductor device can be attained, for example, it becomes realizable [ a high brightness short wavelength light emitting device ].

[0086] Moreover, since crystal growth is selectively carried out so that the Bth page from which the polarity of the layer formed on a substrate is controlled, and a V type element serves as a subject, i.e., N side, may counter with a substrate, a rearrangement and distortion decrease by leaps and bounds, and the Gax Aly In1-x-y N crystal growth of a low defect of them becomes possible. Since it becomes possible to grow up in such the result, for example, a thick cladding layer of a carrier that it be enough to shut up, high performance-ization of the semiconductor device which has pn junction can be attained, and it becomes realizable [ a high brightness short wavelength semi-conductor light emitting device ].

[0087] Furthermore, creation of p type layer of raising and low resistance is attained in the rate of activation of p mold dopant by growing up, capping n type layer, after growing up p type layer, and controlling picking ****** of the hydrogen to p type layer, as p type layer is not exposed to hydrogen by the cooling process. And by using p mold conductivity substrate as a substrate, contact resistance and series resistance can be decreased substantially, and it becomes realizable [ a high brightness short wavelength semi-conductor light emitting device ] by it.

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[Translation done.]



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DESCRIPTION OF DRAWINGS

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[Brief Description of the Drawings]

[Drawing 1] Property drawing showing change of the lattice constant to the temperature of GaN and 3C-SiC.

[Drawing 2] The mimetic diagram showing each for Si side and C side of a SiC substrate front face

[Drawing 3] The mimetic diagram showing the GaN layer from which field bearing which carried out crystal growth on the sapphire substrate differs, respectively.

[Drawing 4] The sectional view showing the outline of the semiconductor laser concerning one example of this invention.

[Drawing 5] Drawing showing roughly the configuration of the growth equipment used in order to manufacture the semiconductor laser shown in drawing 4 .

[Drawing 6] The sectional view showing roughly the configuration of LED concerning other examples of this invention.

[Drawing 7] The sectional view showing the condition of having embedded the LED chip in the resin case.

[Drawing 8] The sectional view showing roughly the configuration of the semiconductor laser concerning other examples of this invention.

[Drawing 9] The sectional view showing roughly the configuration of the semiconductor laser concerning the example of further others of this invention.

[Drawing 10] The sectional view showing roughly the configuration of the semiconductor laser concerning other examples of this invention.

[Drawing 11] The sectional view showing roughly the configuration of the semiconductor laser concerning other examples of this invention.

[Drawing 12] The sectional view showing roughly the configuration of the semiconductor laser concerning other examples of this invention.

[Drawing 13] The sectional view showing roughly the configuration of the semiconductor laser concerning other examples of this invention.

[Drawing 14] The sectional view showing roughly the configuration of the semiconductor laser concerning other examples of this invention.

[Drawing 15] The sectional view showing roughly the configuration of the semiconductor laser concerning other examples of this invention.

[Drawing 16] The sectional view showing roughly the configuration of the semiconductor laser concerning other examples of this invention.

[Drawing 17] The sectional view showing roughly the configuration of the semiconductor laser concerning other examples of this invention.

[Drawing 18] The sectional view showing roughly the configuration of the semiconductor laser concerning other examples of this invention.

[Description of Notations]

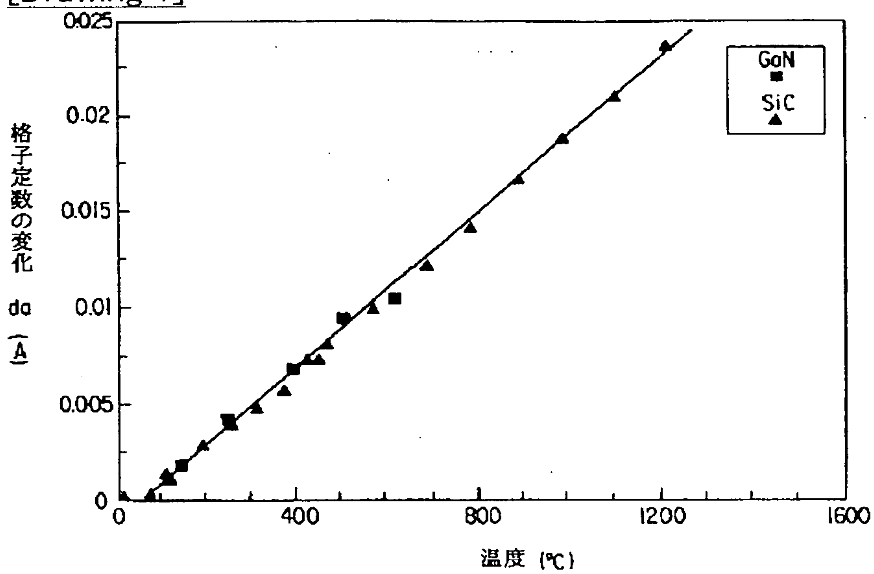
1 -- 3C-SiC substrate
2 -- GaN buffer layer
3 -- Cladding layer
4 -- Luminous layer
5 -- Cladding layer
6 -- Current blocking layer
7 8 -- Metal electrode



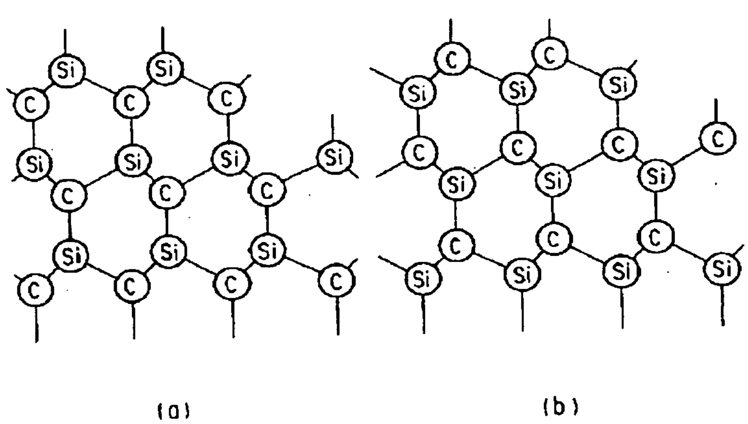
[Translation done.]

## DRAWINGS

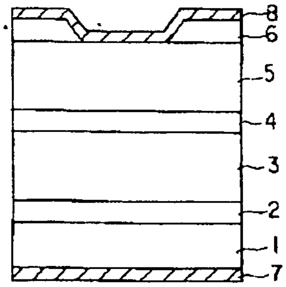
[Drawing 1]



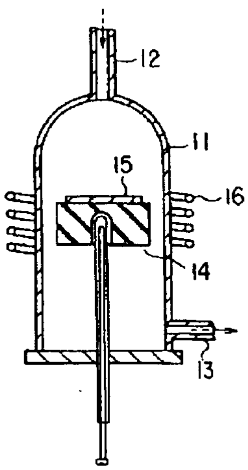

[Drawing 2]



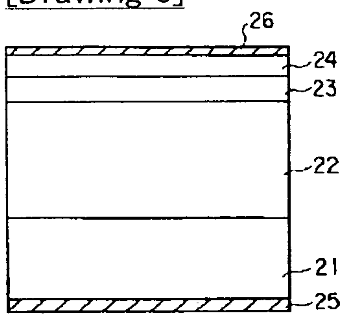

[Drawing 4]



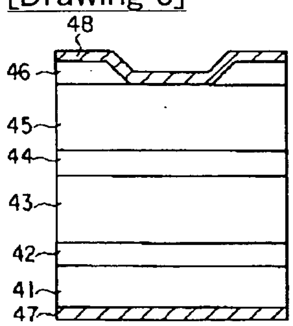

[Drawing 5]



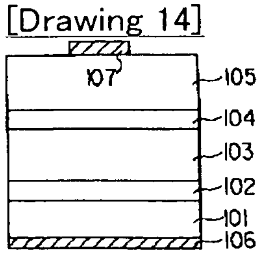

[Drawing 6]



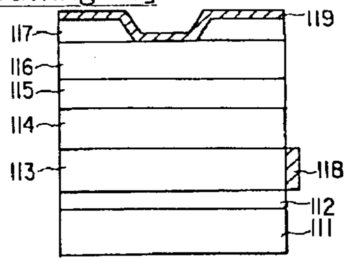

[Drawing 8]



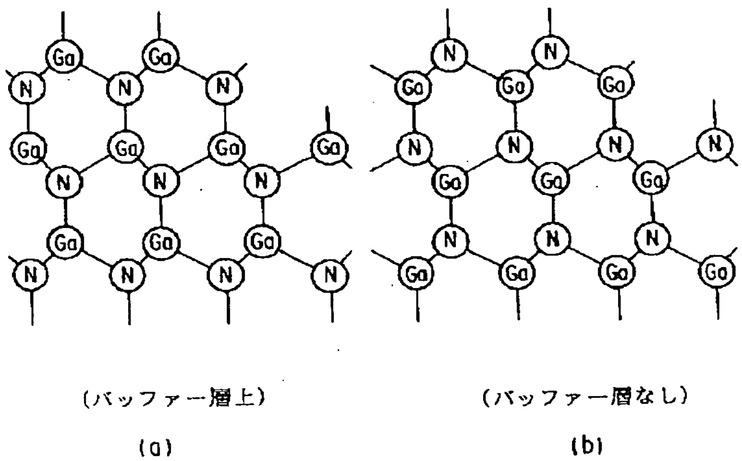

[Drawing 14]



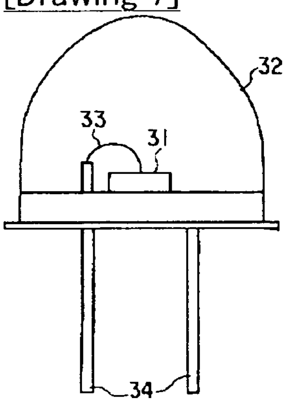
[Drawing 15]



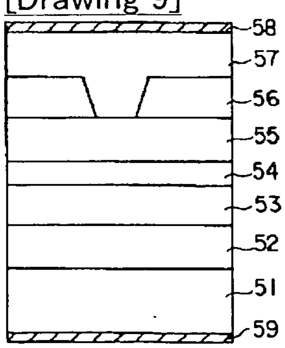

[Drawing 3]



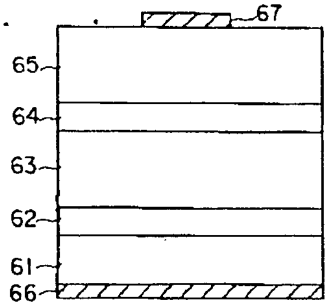

[Drawing 7]



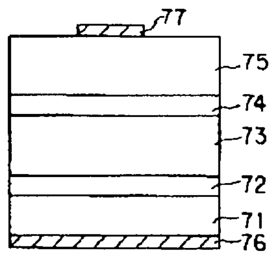

[Drawing 9]



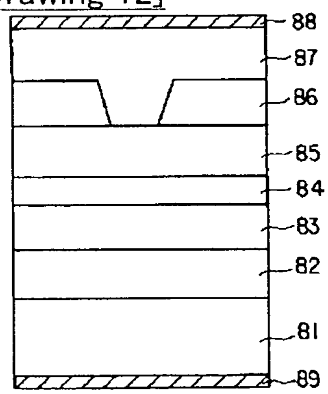

[Drawing 10]



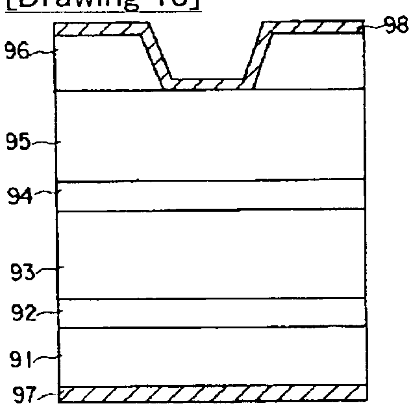

[Drawing 11]



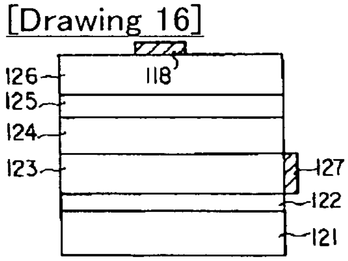

[Drawing 12]



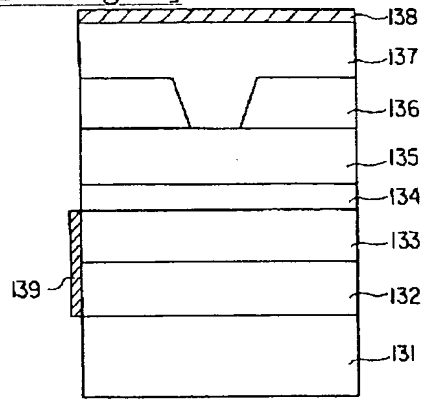

[Drawing 13]



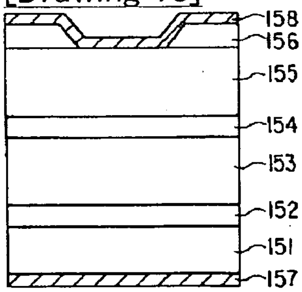

[Drawing 16]



[Drawing 17]




[Drawing 18]




[Translation done.]